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MAMMALS OF HAZELDELL MEADOW STATE NATURE PRESERVE: A THREATENED HIGHLAND RIM ECOSYSTEM, PULASKI COUNTY, KENTUCKY

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ABSTRACT

Hazeldell Meadow State Nature Preserve, Pulaski County, Kentucky, is an endangered, state-protected ecosystem, and it is one of only two protected sites of its kind on the Highland Rim. There are three distinct habitats in the preserve including a wet flatwood, a wet meadow, and a small weedy and native grass area. Each is comprised of ecologically unique plant communities. This preserve is one of the most botanically biodiverse sites in Kentucky but faces threats from surrounding agricultural practices, logging of adjacent woodlands, and climate change resulting from global warming. Recognition of shifts in the future biodiversity requires documentation of the current diversity of taxonomic groups. The purpose of this study was to provide baseline data on mammals for comparison with future research. Data were gathered from 2012 to 2026 using bat detectors, coverboards, mist nets, nest boxes, traps, observations, pitfalls, and trail cameras. Thirty-three species of mammals were confirmed in the preserve, with another trapped just outside the preserve's boundary. During the study, population shifts of White-footed Deermice (*Peromyscus leucopus*) and Prairie Voles (*Microtus ochrogaster*) were documented. *Microtus ochrogaster* was first recorded in the meadow in 2022, and *P. leucopus* declined sharply after the arrival of *M. ochrogaster*. It is unlikely these two species influenced each other, such as by competition. Botflies might have caused a decline of *P. leucopus*. Most small mammals were uncommon in the preserve. This is likely due to ecological reasons that are not clear.

Key words: endangered ecosystem, Hazeldell Meadow State Nature Preserve, Highland Rim Wet Meadow, mammal diversity, mammal ecology, wet flatwoods

INTRODUCTION

Hazeldell Meadow State Nature Preserve is an endangered, state-protected ecosystem in Kentucky. Only two such protected sites exist on the Highland Rim geological formation, the other being in Tennessee. This preserve is vulnerable to loss of biodiversity from surrounding agricultural activities, fragmentation from logging on adjacent woodlands, and climate change due to global warming (Krupa et al. 2024). Documenting future changes in the preserve requires generating baseline data. A baseline inventory for plants was conducted by the Office of the Kentucky Nature Preserves Commission, which has an unpublished list of species

(Littlefield et al. 2013). In addition, long-term research during the last 18 years has focused on a state endangered carnivorous plant, the Dwarf Sundew (*Drosera brevifolia*; Krupa 2019; Krupa et al. 2020, 2021; Potts and Krupa 2016). More recently, research has focused on mammals (Tierney et al. 2022; Kruger et al. 2024; Krupa et al. 2024). This current study presents data collected on mammals documented in the preserve during the last 14 years, providing a detailed list of species and their ecology.

SITE DESCRIPTION

The 22.7-hectare Hazeldell Meadow State Nature Preserve (hereafter referred to as Hazeldell Preserve or the preserve; Fig. 1) is a Heritage Land Site located on the Highland Rim in Pulaski County, Kentucky. The property was purchased by The Nature Conservancy in 1997, then sold to Pulaski County Fiscal Court in 2009 through a grant from the Kentucky Heritage Land Conservation Fund, and has since been dedicated as a State Nature Preserve by the Office of Kentucky Nature Preserves Commission.

The Highland Rim is a ring-shaped geological area that extends from southern Kentucky to northern Alabama with the majority encircling the Central Basin of Tennessee. The Highland Rim is characterized by an uplift that forms a sharply pronounced escarpment on the outside of the rim and with gentle slopes into the Central Basin. The preserve is on Robertsville soil comprised of poorly drained silt loam, which occasionally floods and is considered partially hydric (Forsythe 1993). The soil consists of a fragipan, which is an

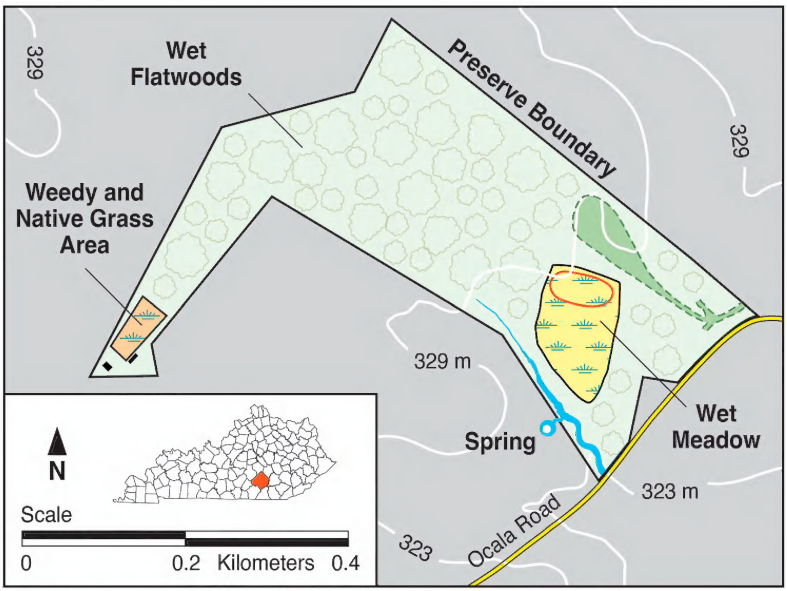

Figure 1. Kentucky state map showing the location of Hazeldell Meadow State Nature Preserve in Pulaski County (inset). The map shows the three communities—wet flatwoods, wet meadow, and the weedy and native grass area—within the preserve. The white lines represent elevation contours for 323 m and 329 m. The red oval is the abandoned go-kart track; the green enclosed in dashed line is the low wet area; the blue line is the intermittent stream with location of a spring; the black rectangles represent two small outbuildings.

impermeable or slowly permeable layer that restricts penetration by plant roots. This creates a shallow, perched water table causing seasonally saturated soils from late fall to late spring. This leads to occasional flooding in some areas of the preserve.

The preserve contains three distinct plant communities within a region that is a mosaic of wooded areas and agricultural land comprised of a mix of annual crops and pastures. These plant communities are described below.

Wet flatwoods.—Ninety-six percent (21.9 ha) of the preserve is a wet flatwoods community (hereafter referred to as flatwoods; Fig. 1). These woods were probably last logged 40 years ago, but the specific year or at what intervals trees were harvested is not known. Old, weathered tree stumps remain from past logging events. The flatwoods are dominated by Red Maple (*Acer rubrum*), American Beech (*Fagus grandifolia*), American Holly (*Ilex opaca*), Tulip Poplar (*Liriodendron tulipifera*), Sweet Gum (*Liquidambar styraciflua*), Black Gum (*Nyssa sylvatica*), White Oak (*Quercus alba*), Southern Red Oak (*Q. falcata*), and Black Oak (*Q. velutina*). Relatively few herbaceous plants grow in the understory. Slight, subtle variation in topography creates a mosaic of ecological conditions ranging from higher areas where standing water never occurs (Fig. 2) to lower areas where standing water occurs during winter and spring (Fig. 3) with intermediate areas (Fig. 4). Much of the flatwoods has a mid-story dominated by American Holly and American Beech. Few large, old oaks occur and are scattered through the flatwoods. Shagbark Hickory (*Carya ovata*) and Pignut Hickory (*C. glabra*) also are scattered through the flatwoods but are nowhere common. In other areas, dense thickets of small, younger trees occur.

Wet meadow.—The 0.81-hectare wet meadow community (hereafter referred to as meadow; Fig. 1 and Fig. 5) is in the southern portion of the preserve. It is poorly drained and more prone to seasonal standing water than the flatwoods. Standing water is infrequent from mid-June to mid-November. The meadow gently slopes towards an intermittent stream to the southwest (Fig. 1). The Bluegrass Crayfish (*Cambarus batchi*)

Figure 2. Driest and highest elevation area of wet flatwoods dominated by yellow poplar, multiple species of oaks, and red maple. Photograph taken 2 January 2025.

Figure 3. The wettest area of the flatwoods along the eastern boundary of the forest. Photograph taken on 10 April 2025.

Figure 4. Wet flatwoods dominated by American Beech trees located between wet meadow and Ocala Road. Photograph taken on 6 September 2021.

Figure 5. Hazeldell wet meadow. Photographs taken on: a) 10 November 2021; and b) 29 July 2021.

is an abundant burrowing species especially in the meadow where it creates small-scale disturbance by bringing soil to the surface causing bare patches (Krupa et al. 2021).

The meadow is dominated by grasses and sedges (Thompson 2021). It has a diverse plant community of 200 species of graminoids, forbs, and woody plants in a unique combination of grassland and wetland species (Littlefield et al. 2013). It supports 25 species of asters (Family Asteraceae), 22 species of grasses (Family Poaceae), 16 species of sedges (Family Cyperaceae), 11 species in the rose family (Family Rosaceae), 8 species of legumes (Family Fabaceae), 7 species of rushes (Family Juncaceae), 7 species of orchids (Family Orchidaceae), and other species representing 55 families (Thompson 2021).

The meadow is managed to remain open habitat. It was burned most recently on 10 March 2025, 17 November 2020 (Fig. 6), and 20 November 2012. Fires leave Eastern Harvest Mouse (*Reithrodontomys humulis*) nests exposed (Fig. 7) and the 2025 fire left *M. ochrogaster* runs exposed (Fig. 8). The 2012 and 2025 prescribed burns were considered hot fires that killed most of the portions of woody plants above ground. The 2020 prescribed burn was a cool fire that left patches of the meadow unburned and many tree saplings were not killed. The meadow was mowed in the fall of 2016. Mowing was close to the ground with no vegetation standing more than 20 cm. During the summer of 2018, many saplings were cut at ground level and the bases treated with herbicide. In October and November 2023, saplings were again cut and treated.

On the eastern side of the meadow is an area with compressed, depressed soil where standing water persists the longest in the preserve. This is the remnant of a go-kart racetrack that was in use for 20 years until 1986 (Fig. 1). The plant community in the racetrack is distinctly different than other parts of the meadow. There are few woody plants, while sedges including Slender Spikerush (*Eleocharis tenuis*), Small-headed Beakrush (*Rhynchospora capitellata*), and Longleaf Panicum (*Panicum longifolium*) dominate. This is where 98% of the state-endangered Dwarf Sundew grows in the preserve.

Weedy and native grass area.—A 4.1 ha section along the northern boundary of the preserve was purchased in 2001 (Fig. 9). At the northwestern end of this is the weedy and native grass area (hereafter referred to as the weedy area) of approximately 1,500 m^2 (Fig. 1). It is mostly surrounded by heavily grazed woods and pasture to the south, west, and north. Preserve flatwoods are to the east. This area is prone to seasonal standing water. A house and several outbuildings once stood here, but only two outbuildings remain (locations shown in Fig. 1). Small patches of domestic plants persist including Dutch irises (*Iris* × *hollandica*), Daylilies (*Hemerocallis* sp.), Daffodils (*Narcissus*), and Lily-of-the-Valley (*Convallaria majalis*), mostly near the outbuildings. Cattle grazed this area up to 2001.

The eastern half of the weedy area is dominated by Bentgrass (*Agrostis perennans*), Broom Sedge (*Andropogon virginicus*), Bushy Bluestem (*A. glomeratus*), Shortbeard Plumegrass (*Saccharum brevibarbe*), and Little Bluestem (*Schizachyrium scoparium*). The western half is dominated by Bosc's Panicgrass (*Dichanthelium boscii*), Deertongue (*D. clandestinum*), Nimbleweed (*Muhlenbergia scheberi*), and *A. perennans*. The western portion also has non-grass species including multiple species of sedges (*Carex* sp.), Common Rush (*Juncus effuses*), Poison Ivy (*Toxicodendron radicans*), Allegheny Blackberry (*Rubus allegheniensis*), and saplings of multiple species of trees. Herbaceous weedy non-natives include Chickweed (*Cerastium glomeratum*), Queen Anne's Lace (*Daucus carota*), Japanese Honeysuckle (*Lonicera japonica*), and Multiflora Rose (*Rosa multiflora*). In 2024, saplings and small trees were removed to maintain this area as an open meadow.

Figure 6. Prescribed burn of wet meadow that occurred on 17 November 2020.

Figure 7. *Reithrodontomys humulis* nests: a) nest found on 18 December 2012 after the prescribed burn on 20 November 2012; and b) nest in meadow on 2 December 2023 when there was no preceding prescribed burn.

Figure 8. *Microtus ochrogaster* runs in the meadow exposed after the 10 March 2025 prescribed burn. Photograph taken on 10 March 2025.

Figure 9. Weedy and native grass area dominated by grasses and sedges. Photograph taken on 2 November 2025.

METHODS

Live trapping.—Periodically from 2012 to 2025, Sherman live traps (H.B. Sherman Traps, Inc., Tallahassee, FL) were set in the three communities. For tree squirrels, #102 Tomahawk traps (Tomahawk Live Trap, Hazelhurst, WI) were secured to wooden platforms attached to trees and baited with a peanut butter-oatmeal mix. These traps were set on multiple occasions from December 2022 to April 2026.

Mole trapping.—Three types of mole traps were set from 2022 to 2025, including Wire Tek traps (Wire-Tek, Inc., Sunman, IN), Victor plunger style mole traps and Victor Out O' Sight mole traps (Woodstream Corporation, Lititz, PA).

Pitfalls.—During January and February 2016, and again during January and February 2020, 0.9-liter plastic yogurt containers were set in the meadow. From December 2024 to June 2025, 40 pitfalls were set at two locations in the flatwoods, one was at a site where there was no standing water, and the second area at a site where there was standing water for half of the year (Fig. 3). All pitfalls were set next to rotting logs and large, fallen tree limbs.

Trail cameras.—From February to March 2020, 14 Bushnell HD trail cameras (Bushnell, Overland Park, KS) were set in the flatwoods. Most of them were aimed at bait stations that included a jar of peanut butter, a container of lard, and a can of sardines all attached to trees at various heights (see Tierney et al. 2022 for details). These cameras also photographed mammals moving through the flatwoods not attracted to bait. Some cameras were not aimed at bait. From 3 September 2022 to 26 March 2023, 15 Bushnell HD trail cameras were set in the flatwoods. This effort focused on carnivores. The cameras were aimed at trees on which a variety of commercial predator scent were attached (see Kruger et al. 2024 for details). These cameras also photographed species behind the trees moving by but not attracted to scents.

Wooden nest boxes.—Sixty-five wooden boxes were placed in the meadow. These were 14 cm x 11 cm x 21 cm with an 18 mm diameter hole that was 5 cm deep. The hole design prevented raccoons from reaching inside. Cotton was placed in each box. They were placed on the ground and attached to wooden stakes. Boxes remained in the meadow from 23 December 2023 until checked and removed on 16 November 2024. This was an effort to assess the number of *R. humulis* in the meadow. *Reithrodontomys humulis* is thought to be trap shy, which could result in population underestimates (Mumford and Whitaker 1982). However, they readily make winter nests in human-made structures like cans with cotton (Dunaway 1968), thus providing them with nest boxes may be a better way to estimate the population by counting mice in boxes.

Mist netting and observations.—There is no standing water in Hazeldell Preserve over which to set nets. Instead, on 10 separate occasions in 2023 and 2024, nets were set across openings between a pasture and the flatwoods, and openings between the meadow and the flatwoods. Furthermore, sunset observations were made of flying bats over the meadow on 10 occasions in 2023 and 2024.

Coverboards.—On 20 April 2025, 10, 0.4 m^2 plywood boards were placed on the ground in the flatwoods and checked periodically. This was to determine if species such as Woodland Voles (*Microtus pinetorum*) or Northern Short-tailed Shrews (*Blarina brevicauda*) were more abundant in the flatwoods than indicated by trapping. On 8 September 2025, 25 small Sherman live traps were set adjacent to five of the coverboards showing small mammal activity beneath.

Bat detectors.—Gregg Janos (Biologist with the Office of the Kentucky Nature Preserves Commission) placed two Kaleidoscope Pro bat detectors (KPro, version 5.6.8, Wildlife Acoustics, Inc., Maynard, MA) in the preserve from 27 May to 1 June 2025. One was placed in the meadow and the other in the flatwoods where it was fairly open under the canopy due to few mid-story trees. Janos also analyzed the data collected by these devices. The resulting acoustic files were identified when possible. The program considered eight species that could occur in the preserve including: Big Brown Bat (*Eptesicus fuscus*), Eastern Red Bat (*Lasiurus borealis*), Hoary Bat (*L. cinereus*), Silver-haired Bat (*Lasionycteris noctivagans*), Small-footed Bat

(*Myotis leibii*), Little Brown Bat (*M. lucifugus*), Northern Long-eared Bat (*M. septentrionalis*), Indiana Bat (*M. sodalis*), and Evening Bat (*Nycticeius humeralis*). Maximum likelihood estimates were calculated with $p < 0.05$ as the cutoff for considering the species present.

Voucher specimens.—A minimum number of voucher specimens were kept during this study as the research was conducted on a protected preserve. Voucher specimens are listed in each species account. Other than bats, all other species are documented via photographs from trail cameras. All vouchers will be deposited in the University of Kansas Biodiversity Institute, Lawrence. Currently, they are held at the University of Kentucky Department of Biology for on-going research studies.

RESULTS

A total of 33 mammalian species were documented in Hazeldell Meadow State Nature Preserve, with one species, House Mouse (*Mus musculus*), trapped 8 m west of the preserve boundary. These species include: Virginia Opossum (*Didelphis virginiana*), Eastern Cottontail (*Sylvilagus floridanus*), *M. ochrogaster*, *M. pinetorum*, Southern Bog Lemming (*Synaptomys cooperi*), *P. leucopus*, *R. humulis*, Southern Flying Squirrel (*Glaucomys volans*), Eastern Gray Squirrel (*S. carolinensis*), Eastern Fox Squirrel (*Sciurus niger*), Northern Meadow Jumping Mouse (*Zapus hudsonius*), *Blarina brevicauda*, Least Shrew (*Cryptotis parvus*), Southeastern Shrew (*Sorex longirostris*), Eastern Mole (*Scalopus aquaticus*), *E. fuscus*, *L. cinereus*, *L. borealis*, *L. noctivagans*, *N. humeralis*, *P. subflavus*, Striped Skunk (*Mephitis mephitis*), Long-tailed Weasel (*Neogale frenata*), American Mink (*N. vison*), Northern Raccoon (*Procyon lotor*), American Black Bear (*Ursus americanus*), Domestic Dog (*Canis familiaris*), Coyote (*C. latrans*), Northern Gray Fox (*Urocyon cinereoargenteus*), Red Fox (*Vulpes vulpes*), Domestic Cat (*Felis catus*), Bobcat (*Lynx rufus*), and White-tailed Deer (*Odocoileus virginianus*). The number of small mammal species documented in the three communities is shown in Table 1. The meadow had nine species, the flatwoods had eight, and the weedy area had six.

Five hundred pitfall nights were accumulated in the meadow during the winters of 2016 and 2020. One *R. humulis* was captured (Table 2). A total of 5,080 pitfall nights were accumulated in the flatwoods from 28 December 2024 to 10 June 2025. One *B. brevicauda* and two *S. longirostris* were captured (Table 2).

From 2012 to 2026, a total of 6,441 small mammal traps were set in the three communities (Tables 3 and 4). From 2022 to 2025, 528 mole trap nights were set in both the meadow and the flatwoods (Table 2). Five *S. aquaticus* were captured, all in Wire Tek traps.

Of the 65 wooden nest boxes, only one had a *R. humulis* nest. It was made of dry, finely shredded grass. Nine boxes had *P. leucopus* nests, which were identified by the cotton reshaped to fill the box with a chamber in the center. The size of droppings also indicated this species. Two boxes each had two adult *P. leucopus*. Nine boxes had all the cotton removed, which mice probably took to make nests elsewhere.

A total of 34,071 photos were taken from 1 February to 28 March 2020, of which 553 had images of 12 species of mammals. The four most photographed species were *S. carolinensis*, *D. virginiana*, *P. leucopus*, and *O. virginianus* (Table 5). These species were in 91% of the photos (Tierney et al. 2022). From 3 September 2022 to 26 March 2023, a total of 37,193 photos were taken of which 525 had images of nine species of carnivores (Kruger et al. 2024). The six most photographed carnivores were *P. lotor*, *C. latrans*, *C. familiaris*, *M. mephitis*, *L. rufus*, and *V. vulpes* (Table 6). These species were in 98% of the photos of carnivores.

Of the photos taken during spring 2020, only four were of *G. volans*. These were taken on 16 March and 18 March (Tierney et al. 2022). Of the photos taken in the fall of 2022 and spring of 2023, *G. volans* were photographed five times. These were on 7 September, 13 September, 1 October, 14 October, 15 October, and 28 October 2022. They were not photographed in the spring of 2023. None were caught in tomahawk traps set for them on 4 March 2023, 15 December 2023, 26 December 2024, and 26 October 2025. A total of seven were trapped on 15 April 2023, 10 March 2025, 22 March 2025, 27 April 2025, and 26 April 2026.

Table 1. Species of small mammals (defined as rodents, moles, and shrews) found in the three plant communities of Hazeldell Meadow State Nature Preserve.

	Habitat		
Species	Flatwoods	Meadow	Weedy and Native Grass Area
Blarina brevicauda	X	X	X
Cryptis parvus		X	
Sorex longirostris	X		
Scalopus aquaticus	X	X	X
Microtus ochrogaster		X	
Microtus pinetorum	X	X	X
Synaptomys cooperi		X	
Peromyscus leucopus	X	X	X
Reithrodontomys humulis		X	X
Zapus hudsonius		X	X
Glaucomys volans	X		
Sciurus niger	X		
Sciurus carolinensis	X		
Total species	8	9	6

Networks of runs formed under five of the 10 coverboards by mid-summer. With all five of these, one to two tunnels that were 3 cm below ground led away from the coverboards. Five *P. leucopus* were trapped next to four of the coverboards on 8 September 2025. *Peromyscus leucopus* were found in the runs when coverboards were lifted on three occasions. Each time they escaped into a tunnel entrance. No other species of small mammals were found under coverboards.

A total of 2,402 files were identified as bats and of those 1,520 were identified to species by Kaleidoscope Pro bat detectors (Table 7). Files identified as species not likely in the preserve were removed. The Kaleidoscope program identified the presence of *E. fuscus*, *L. cinereus*, *L. borealis*, *L. noctivagans*, *M. sodalis*, *N. humeralis*, and *P. subflavus*. After manual vetting, *M. sodalis* was removed as these files were more likely of *L. borealis*, which sound similar in forest habitat under the canopy. There was only one significant maximum likelihood estimate ($p = 0.012$) for *N. humeralis* in the flatwoods on 1 June 2025 (Table 8), thus the certainty of identification is questioned (Gregg Janos, pers. com.). Identification in the meadow was more certain (Table 8). *Eptesicus fuscus*, *L. cinereus*, *L. borealis*, *L. noctivagans*, and *P. subflavus* were confirmed as present in the preserve with certainty. Four species were observed flying over the meadow at dusk. These include *E. fuscus*, *L. borealis*, *N. humeralis*, and *P. subflavus*. In addition, a female *L. cinereus* was found dead at the edge of the meadow on 20 July 2023.

Table 2. Number of captures for each small-mammal species using mole traps, tomahawk traps on platforms attached to trees, pitfall traps in wet meadow and wet flatwoods. Values in parentheses represent trap success per 100 trap nights.

Trap type	Trap nights	*Scalopus aquaticus*	*Sciurus carolinensis*	*Glaucomys volans*	*Reithrodontomys humulis*	*Sorex longirostris*	*Blarina brevicauda*
Mole traps	528	5 (0.9%)					
Tomahawk traps in trees	248		5 (2.0%)	7 (2.8%)			
Pitfalls in Wet Meadow	510				1 (0.2%)		
Pitfalls in Wet Flatwoods	5,080					2 (0.04%)	1 (0.02%)

Table 3. Number of captures for each small-mammal species in the wet meadow from 2012 to 2023 at Hazeldell Meadow State Nature Preserve. Also shown are the number of trap nights during each period (data from Krupa et al. 2024 and additional trapping in 2025). Values in parentheses represent trap success per 100 trap nights.

Year	Trap Nights	*Blarina brevicauda*	*Cryptotis parvus*	*Peromyscus leucopus*	*Reithrodonto-mys humulis*	*Microtus ochrogaster*	*Microtus pinetorum*	*Synaptomys cooperi*	*Zapus hudsonius*
2012–2016	384	0	0	3 (0.8%)	1 (0.3%)	0	0	0	0
2020	1,424	2 (0.1%)	0	138 (9.7%)	5 (0.4%)	0	0	2 (0.1%)	1 (0.07%)
2022	790	1 (0.1%)	0	16 (2.0%)	2 (0.3%)	23 (2.9%)	0	0	0
2023	1,936	5 (0.3%)	0	10 (1.8%)	5 (0.3%)	37 (1.9%)	2 (0.1%)	1 (0.05%)	0
2025	570	0	1 (0.2%)	10 (1.8%)	4 (0.7%)	3 (0.5%)	0	0	0
Totals	5,104	8 (0.2%)	1 (0.02%)	177 (3.5%)	17 (0.3%)	63 (1.2%)	2 (0.04%)	3 (0.06%)	1 (0.02%)

Table 4. Number of captures for each small-mammal species in the wet flatwoods (Flatwoods) from 2012 to 2025 and native grass and weedy area (Weedy Area) at Hazeldell Meadow State Nature Preserve. Also shown are the number of trap nights during each period (data from Krupa et al. 2024 and additional trapping in 2025). Values in parentheses represent trap success per 100 trap nights. Note that of the 46 *P. leucopus* captures in the flatwoods, 27 were caught on a single night (4 September 2022).

Habitat	Trap nights	*Blarina brevicauda*	*Peromyscus leucopus*	*Reithordondomys humilis*	*Microtus pinetorum*	*Zapus hudsonius*
Flatwoods	965	4 (0.4%)	46 (4.8%)	0	1 (0.1%)	0
Weedy Area	372	2 (0.5%)	13 (3.5%)	4 (1.1%)	1 (0.3%)	1 (0.3%)

Table 5. A total of 553 photographs were taken with trail cameras set in the wet flatwoods from 1 February 2020 to 28 March 2020. Data from Tierney et al. (2022).

Species	Number of Images	Percentage of Images
Sciurus carolinensis	204	36.9%
Didelphis virginiana	119	21.5%
Peromyscus leucopus	94	17.0%
Odocoileus virginianus	87	15.7%
Sylvilagus floridanus	15	2.7%
Canis latrans	8	1.4%
Lynx rufus	6	1.1%
Procyon lotor	6	1.1%
Mephitis mephitis	5	0.9%
Glaucomys volans	4	0.7%
Urocyon cinereoargenteus	3	0.5%
Sciurus niger	2	0.4%

Table 6. A total of 525 images (photographs and videos) taken by trail cameras set in the wet flatwoods from 3 September 2022 to 26 March 2023. Data from Kruger et al. (2024).

Species	Number of Images	Percentage of Images
Procyon lotor	305	58.1%
Canis latrans	79	15.1%
Canis familiaris	55	10.5%
Mephitis mephitis	41	7.8%
Lynx rufus	24	4.6%
Vulpes vulpes	12	2.3%
Neogale frenata	4	0.8%
Neogale vison	3	0.6%
Felis catus	2	0.4%

Table 7. Results of the number of files collected from Kaleidoscope Pro bat detectors set out in the wet meadow (Meadow) and in the wet flatwoods (Flatwoods) from 27 May to 1 June 2025.

Habitat	Date	*Eptesicus fuscus*	*Lasiurus cinereus*	*Lasiurus borealis*	*Lasionycteris noctivagans*	*Nycticeius humeralis*	*Perimyotis subflavus*
Meadow	27 May	6	4	32	7	1	0
	28 May	4	2	27	10	4	2
	29 May	7	2	28	7	3	1
	30 May	5	1	1	3	0	0
	31 May	14	9	22	7	7	0
	1 June	0	0	6	0	2	1
Total		36	18	116	34	17	4
Flatwoods	27 May	1	0	146	5	5	2
	28 May	1	0	183	0	36	5
	29 May	1	0	215	0	14	19
	30 May	0	0	98	1	6	20
	31 May	0	0	342	0	37	17
	1 June	2	1	39	6	20	15
Total		5	1	1,023	12	118	78

Table 8. Maximum likelihood estimate that Kaleidoscope Pro calculated for each species being present. Maximum likelihood estimates were calculated with $p < 0.05$ as the cutoff for considering the species present. Significant values are indicated in bold.

Habitat	Date	*Eptesicus fuscus*	*Lasiurus borealis*	*Lasiurus cinereus*	*Lasionycteris noctivagans*	*Nycticeius humeralis*	*Perimyotis subflavus*
Meadow	27 May	**0.007**	**< 0.000**	**0.005**	**0.033**	1	1
	28 May	0.168	**< 0.000**	0.206	**0.000**	1	0.889
	29 May	**0.001**	**< 0.000**	0.224	**0.017**	1	1
	30 May	**0.002**	0.178	0.532	0.347	1	1
	31 May	**0.000**	**< 0.000**	**< 0.000**	0.472	0.630	1
	1 June	1	**< 0.000**	1	1	0.854	0.698
Flatwoods	27 May	0.874	**< 0.000**	1	**0.001**	1	1
	28 May	0.106	**< 0.000**	1	1	1	1
	29 May	0.099	**< 0.000**	1	1	1	0.636
	30 May	1	**< 0.000**	1	0.189	1	**< 0.001**
	31 May	1	**< 0.000**	1	1	1	1
	1 June	**0.031**	**< 0.000**	0.232	1	**0.012**	**< 0.001**

SPECIES ACCOUNTS

ORDER DIDELPHIMORPHIA
Family Didelphidae
***Didelphis virginiana* (Kerr, 1792)**
Virginia Opossum

Didelphis virginiana is an abundant, statewide species common in both urban and agricultural areas, and is especially common in locations that are a mosaic of woods, streams, and agriculture. It is described as a generalist, opportunist, and scavenger. *Didelphis virginiana* is one of the most common mammals in the preserve's flatwoods. They were the second most photographed species in 2020 (Table 5; Tierney et al. 2022). Multiple individuals appear in photographs revealing a wide range in both body mass and color varying from almost black to almost white. When cameras have been mounted and aimed at dead animals set out in the preserve, opossums arrived the first evening and returned repeatedly until the carrion was gone. *Didelphis virginiana* was strictly nocturnal. They were not active until well after sunset and they are not photographed after the first hint of morning light.

ORDER LAGOMORPHA
Family Leporidae
***Sylvilagus floridanus* (Allen, 1890)**
Eastern Cottontail

Of the three species of rabbits in Kentucky, *S. floridanus* is the most common species with a statewide distribution. It is common in urban areas, and most common in upland thickets and brushy farmland (Barbour and Davis 1974). Trail cameras showed *S. floridanus* occurs in the flatwoods despite having little ground cover to hide (Table 5). They are abundant in the meadow although they are well concealed in thick vegetation and generally remain undetected. After the 2020 and 2025 prescribed burns, a large number of droppings were found in distinct piles throughout the meadow revealing rabbits spend significant time there. On multiple occasions, parts of *S. floridanus* were found in the flatwoods indicating predation. There are several potential predators in the preserve including Great Horned Owls (*Bubo virginianus*), Barred Owls (*Strix varia*), *C. latrans*, *L. rufus*, and *V. vulpes*.

ORDER RODENTIA
Family Cricitidae
***Microtus ochrogaster* (Wagner, 1842)**
Prairie Vole

Microtus ochrogaster is the most common and widely distributed vole in Kentucky, absent only from the highest mountains in the southeastern part of the state. The first *M. ochrogaster* was trapped in the meadow during the fall of 2022. They were the most frequently trapped species in 2022 and 2023 (Table 3). The appearance of *M. ochrogaster* in the meadow marked a significant shift in the small mammal community composition. In 2020, *P. leucopus* were captured 138 times compared to 146 times for all small mammals. In 2022, *M. ochrogaster* were captured 23 times compared to 16 times for *P. leucopus*. In 2023, *M. ochrogaster* were captured 37 times compared to 10 times for *P. leucopus* (Table 3). The meadow, being wet, does not seem like good habitat for *M. ochrogaster* as they are generally thought to occur in drier habitats in the state/region (Barbour and Davis 1974). Barbour and Davis (1974) noted that they do occupy wet habitat in the absence of Eastern Meadow Voles (*M. pennsylvanicus*), which are not known from Pulaski County (Fassler 1974). Before the prescribed burn on 10 March 2025, vole runs were abundant and well entrenched into the soil (Fig. 8) as they were in 2023. Much of the soil in the meadow has a thick layer of various mosses including Sphagnum (*Sphagnum* sp.). Vole runs cut through the moss down to the soil. The mean depth of runs was 2.7 cm (range, 0.8 cm to 5.0 cm; n = 33) and the mean width was 3.1 cm (range, 1 cm to 4.5 cm; n = 12). On 12 March, *M. ochrogaster* was still in the meadow. There were signs of them excavating burrows as fresh soil was pushed out of burrow entrances. Three trail cameras were set in the meadow on 12 March revealing *V. vulpes* and *P. lotor* in the freshly burned meadow, apparently hunting. On 25 March, excavated vole nests were found on the surface apparently dug up by predators. Vole runs were not maintained after the fire and no evidence of them was visible by late April. On 25 March, 75 small Sherman live traps were set in vole runs close to burrow entrances. No voles were captured. None were caught in 155 traps set on 11 May or in 185 traps set on 8 September. Some *M. ochrogaster* apparently survived the fire as two adults and one juvenile were caught in 155 traps set on 18 October 2025, which was 222 days after the burn. Where they were during that time is unclear. It is highly unlikely they were living under the leaf litter in the flatwoods. It is also unlikely they immigrated from the surroundings area as there was no sign of *M. ochrogaster* in the pasture to the east, the cornfield to the south, and the fescue field to the west, and none were trapped in these areas. *Microtus ochrogaster* make complex underground burrow systems covering 30,000 cm^2 on average with an average depth of 8.4 cm (Davis and Kalisz 1992). Even though some nests were dug up by predators, the most feasible explanation is that surviving voles spent most of their time in burrows until the vegetation became dense. Six voucher specimens were collected from the meadow (JJK-4624, JJK-4628, JJK-4629, JJK-4709, JJK-4712, JJK-4713).

***Microtus pinetorum* (Le Conte, 1830)**
Woodland Vole

Microtus pinetorum is found throughout Kentucky and is unique in comparison to other voles in the state in that it is semi-subterranean (Le Conte et al. 1853) and maintains family units (FitzGerald and Madison 1983). *Microtus pinetorum* was rarely caught in the preserve. One was trapped twice (26 March and 15 April 2023) in the meadow. This was the only year this species was recorded in the meadow. One *M. pinetorum* was trapped in the flatwoods near Ocala Road (Fig. 1) on 26 March 2022, and another trapped in the weedy area on 2 February 2025. Despite being rarely caught, *M. pinetorum* was found in the three communities (Table 1). The habitat seems suitable for this species as it was in other areas of Pulaski County. For example, 31 were caught on one day 17 km west of the preserve in the town of Eubank on 14 February 1888 (Bailey 1900). These are the type specimens for *Pitymys pinetorum carbonarius* (Handley 1952). Thus, their rarity in the preserve is puzzling. One voucher specimen from the current study was collected from the weedy area (JJK-4996).

***Peromyscus leucopus* (Rafinesque, 1818)**
White-footed Deermouse

Constantine Rafinesque (1818) first described *Peromyscus leucopus* as *Musculus leucopus* with the type locality being Shippingport, Kentucky, which is now within the city limits of Louisville. This is the

most abundant species of mammal in Kentucky found in every conceivable habitat. It was also the most ubiquitous rodent in the preserve and the most trapped small mammal in the meadow before *M. ochrogaster* arrived (Table 3). Forty-six of the 51 small mammals trapped in the flatwoods were *P. leucopus*, and they were 13 of the 21 small mammals trapped in the grassy area (Table 4). They were the only small mammal trapped in trash piles and outbuildings in the northeastern area of the preserve. Twenty-seven of the 46 *P. leucopus* captured in the flatwoods were trapped the same evening (4 September 2022), which distorts the flatwood trap success.

There were few *P. leucopus* in the flatwoods compared to typical hardwood forests in eastern Kentucky. For example, trap success was 4.8% in the flatwoods if including mice caught on 4 September 2022 (Table 3), and 2.4% if excluded. In comparison, trap success was 15% (17 mice in 114 traps) in a hardwood forest 77 km east of Hazeldell Preserve (Krupa unpub. data). This site had a complex understory that had extensive timber fall, woody shrubs, and herbaceous ground cover (Krupa unpub. data). The understory in the flatwoods was much less complex. *Peromyscus leucopus* depends on a complex understory (Anderson et al. 2003; Anderson and Meikle 2006), and they depend on hickory nuts and acorns for food (Byman et al. 2013), neither of which were abundant in the flatwoods. *Odocoileus virginianus* is abundant in the flatwoods (Tierney et al. 2022), and it eats herbaceous ground cover thus competing with *P. leucopus* for resources (Byman et al. 2013).

Drastic shifts of *P. leucopus* captures in the meadow occurred over the duration of this study. Trap success dropped greatly after botfly larvae (*Cuterebra* sp.) were observed parasitizing mice in the fall of November 2020 and fall of October 2022. Botflies are known to be a density-dependent factor reducing the number of *P. leucopus* (Burns et al. 2005). The high trap success in 2020 suggested the mouse population density was high, possibly causing an increase in botflies. Thus, the lower trap success in 2022 and 2023 might have been the result of a decline from botfly parasitism in 2020 through 2022.

Evidence indicates that *P. leucopus* tunnel, at least in the flatwoods. *Peromyscus leucopus* was the only species trapped next to coverboards with runs under them; and in every case, the runs connected to tunnel entrances. These tunnels were 2 cm in diameter, thus clearly smaller than those made by *S. aquaticus*. Furthermore, when found under a board when it was lifted, the mice escaped into the tunnels. This may suggest *P. leucopus* has adjusted to be more subterranean in flatwoods where understory cover on the surface is often lacking. Le Conte et al. (1853) noted for *P. leucopus* "This animal burrows in the ground, forming long galleries…" thus first to suggest *P. leucopus* tunnel. Thirteen voucher specimens were collected from the three habitats (JJK-4627, JJK-4630, JJK-4631, JJK-4632, JJK-4633, JJK-4634, JJK-4635, JJK-4636, JJK-4637, JJK-4638, JJK-4937, JJK-4938, JJK-5001.

***Reithrodontomys humulis* (Audubon nd Bachman, 1841)**

Eastern Harvest Mouse

Reithrodontomys humulis is the smallest mouse in Kentucky. This species has a statewide distribution. Barbour and Davis (1974) considered it uncommon and trap shy in the state. It is most often trapped in unmowed grasses, old fields, and rarely on reclaimed surface mines in eastern Kentucky. *Reithrodontomys humulis* was consistently trapped over the course of this study but always in low numbers. Until 2025, the number of *R. humulis* trapped in the meadow never exceeded two mice for 375 trap nights (0.53% trap success). Typically, only one was caught per night and more often none. They were not caught the first four times traps were set after the meadow was burned on 10 March 2025. However, four *R. humulis* were trapped on 19 October 2025 following the fifth trapping, with 155 traps (2.3% trap success). Their above ground nests were dome-shaped with a single opening (Fig. 7). Nests were well hidden and most easily found after prescribed burns.

The grassy area has become more densely vegetated with grasses and forbs after woody plants were removed in 2024. This is likely why *R. humulis* was first trapped there in October 2025. The 5% trap success in this area was higher than any trap success in the meadow. Two voucher specimens were collected from the meadow (JJK-4289, JJK-4300).

***Synaptomys cooperi* Baird, 1857**
Southern Bog Lemming

Synaptomys cooperi is found throughout Kentucky. It has been described as colonial, but there is little evidence of this in the state, other than suggested by Barbour and Hardjasasmita (1966) who reported a "substantial colony" based on 21 specimens trapped over 10 weeks. However, Rose and Linzey (2021) say there is almost no evidence this species is colonial and social. *Synaptomys cooperi* was another small mammal rarely trapped in the preserve. One was captured at the same trap site on 15 and 21 November 2020; this was presumably the same individual. A second one was trapped at a different location in the meadow on 11 February 2023. Thus, only two individuals were caught during the 13 years of this study. A third *S. cooperi* was captured in the planted fescue field 10 m west of the preserve on 3 March 2025, which is voucher specimen JJK-5000. In Kentucky, *S. cooperi* are only occasionally trapped and often in habitats where *M. pennsylvanicus* are absent (Barbour and Davis 1974). The rarity of this species in the preserve was more extreme than at other locations.

Family Muridae
***Mus musculus* Linnaeus, 1758**
House Mouse

Mus musculus is associated with agriculture, especially annual crops, in Kentucky and to a lesser extent in old fields close to urban areas (Krupa and O'Brien 2022). *Mus musculus* was not captured in the preserve during this study, but a juvenile was trapped in a pasture 8 m from the west boundary on 26 October 2025, which is voucher specimen JJK-5050. With annual crops and pastures surrounding the preserve, the chances of *M. musculus* occurring in the meadow exist.

Family Sciuridae
***Glaucomys volans* (Linnaeus, 1758)**
Southern Flying Squirrel

Glaucomys volans is an inhabitant of mature hardwood forests where there are enough acorns and nuts to eat and old trees with holes, snags, and woodpecker nest cavities for refuge. It occurs across Kentucky where sufficient habitat exists even in urban areas. This habitat was not abundant in the preserve as the flatwoods is a mid-successional forest with few large trees. The *G. volans* population in the preserve appears to be small based on the few photographs of them and the few that were trapped.

Due to relatively few nut-producing trees and the rarity of large, old trees in the preserve, there is a deficiency of suitable habitat to support a large population of *Glaucomys volans*. Competition with the much more abundant *S. carolinensis* could impact *G. volans*. However, there is only one study on competition between flying squirrels and *S. carolinensis*, from which Gonzalas et al. (2008) found *S. carolinensis* had no impact on the Northern Flying Squirrel (*Glaucomys sabrinus*). Thus, competition between the two squirrels in the preserve probably does not impact *G. volans*. It is possible that as the flatwoods mature, the *G. volans* population in the preserve might increase in the future.

Glaucomys volans was not trapped during the winter. It is a social species, and several will stay together in nest cavities any time of year (Linzey 1998). *Glaucomys volans* does not hibernate, but will remain inactive for weeks (Linzey 1998). This might explain why they were not trapped during the winter.

***Sciurus carolinensis* (Gmelin, 1788)**
Eastern Gray Squirrel

Sciurus carolinensis is the most common squirrel in Kentucky and one of the most common species of mammals in the state. They are the most visible of urban mammals. Wherever there are trees, especially oak trees, *S. carolinensis* will be found. The flatwoods do not appear to be prime habitat for *S. carolinensis*, and yet this is one of the two most common species in the preserve. These squirrels were rarely seen or heard in the preserve. They were detected most often when quietly entering the preserve or walking along trails. Even then they were often heard running away over the leaf litter rather than seen. When corn was grown in adjacent fields, corn cobs stripped of kernels with husks still attached were found in the flatwoods, often up in trees, indicating squirrels were traveling off the preserve to forage. They were the most photographed species in the preserve, appearing in nearly 37% of all photos taken (Tierney et al. 2022). Kruger et al. (2024) did not keep count of *S. carolinensis* in photographs, but there were thousands of images showing them investi-

gating commercial predator scent attractants. Sc*iurus carolinensis* rarely makes leaf nests in tree branches as elsewhere. Considering the rarity of hollow trees and large snags, it is not clear where *S. carolinensis* nested. Surprisingly, only six *S. carolinensis* were caught in Tomahawk traps (Table 2), but they were often seen investigating these traps. This suggests *S. carolinensis* is trap shy or trap adverse.

***Sciurus niger* (Linnaeus, 1758)**
Eastern Fox Squirrel

Sciurus niger is common in Kentucky and has a statewide distribution. This species is associated with tree-lined rural roads and the edges of hardwood forests along roads. This squirrel favors open country, fencerows along pastures and cultivated fields especially those with oaks, hickories and walnut trees (Barbour and Davis 1974; Derge and Yahner 2000). The preserve lacked the habitat for *S. niger*; it was never observed and only photographed twice. One photograph was taken at the stream on the western boundary, the other deep in the flatwoods. This squirrel is not a resident of the preserve.

Family Zapodidae
***Zapus hudsonius* (von Zimmermann, 1780)**
Northern Meadow Jumping Mouse

Zapus hudsonius has a patchy distribution in central Kentucky (Campbell et al. 2010). The habitat has been described as abandoned grassy fields, thick vegetation along ponds, lakes, streams, and marshes. Barbour and Davis (1974) describe the habitat as grassland marshes and lakeside weeds. They also said that grasslands that were pure dense stands of only grass were not suitable, but rather "tall, weedy grassland, where plants have enough space between them for mice to forage." It was surprising only two individuals were trapped during the study considering the meadow seemed like ideal habitat. This is a hibernating species that over-winters in burrows (Barbour and Davis 1974). The saturated soil caused by the secondary water table above the fragipan could cause flooding of burrows during the winter. If the meadow becomes drier due to climate change from global warming, it is possible this species will be more common in the meadow in the future. One voucher specimen was collected from the weedy area (JJK-4871).

ORDER EULIPOTYPHLA
Family Soricidae
***Blarina brevicauda* (Say, 1823)**
Northern Short-tailed Shrew

Blarina brevicauda has a statewide distribution in Kentucky. Barbour and Davis (1974) considered this shrew one of the most common mammals in the state. Despite this, *B. brevicauda* was not common in the preserve at the beginning of the study. None were caught in the meadow from 2012 to 2016, with a total of 10 caught in the preserve from 2020 to 2023. A total of four were caught in the flatwoods from 2012 to 2025, and they were not caught in the weedy area until 2025 when two were trapped on 26 October. Thus, this species was caught in all three habitats (Table 1). The habitat appears quite suitable compared to trapping them in similar habitats in other areas of the state, thus it is surprising so few were trapped. Eleven voucher specimens were collected from the three habitats (JJK-4626, JJK-4710, JJK-4930, JJK-4931, JJK-4932, JJK-4933, JJK-4934, JJK-4935, JJK-4936, JJK-5011, JJK-5058).

***Cryptotis parvus* (Say, 1823)**
North American Least Shrew

Barbour and Davis (1974) said *C. parvus* appears rare in Kentucky. However, based on the abundance of their bones in owl pellets, Barbour and Davis (1974) felt *C. parvus* was probably more common in Kentucky than trapping efforts suggested. The first and only *C. parvus*, a female, caught during this study was trapped in the meadow on 19 October 2025, which is voucher specimen JJK-5045.

***Sorex longirostris* (Bachman, 1837)**
Southeastern Shrew

Studies in Kentucky have shown *S. longirostris* to be one of the most rarely caught *Sorex* in the state (Feldhamer et al. 1993; Kiser and Meade 1993) with an uncertain distribution covering the western two-thirds of the state. Two *S. longirostris* were caught on 6 April 2025 and 4 May 2025 in pitfalls next to logs and tree limbs in the wettest area of the flatwoods where rotting woody debris was most abundant (Fig. 1, Fig. 3). Barbour and Davis (1974) described the preferred habitat as swampy lowland weed fields, moist woods, hon-

eysuckle patches, and occasionally dry upland fields. French (1980) described the habitat as having heavy ground cover of grasses, sedges, and rushes with thick mats of decaying leaves, in grassy fields, and in wet areas. In North Carolina, *S. longirostris* were caught more often in bottomland hardwood forests with an abundance of windfall-downed trees and woody debris in an advanced state of decay (Greenberg and Miller 2004; Cromer et al. 2007). This is essentially the microhabitat where the two were caught during this study. Both are voucher specimens (JJK-4998, JJK-5010).

Family Talpidae
***Scalopus aquaticus* (Linnaeus, 1758)**
Eastern Mole

Scalopus aquaticus has a distribution covering the western two-thirds of Kentucky. It does not extend into the Cumberland Plateau (Barbour and Davis 1974) that begins a few kilometers east of the preserve in Pulaski County. In the preserve, *S. aquaticus* was found both in the meadow and the flatwoods, but much less common in the meadow. It was abundant in the flatwoods despite feeding runs only seen occasionally when they crossed a leafless trail or where past flowing water had washed the leaves away. Feeding runs were extremely abundant in the flatwoods and could be found by sweeping away leaf litter. Their deep, permanent tunnels below the surface were extremely abundant to the point of resembling an interconnected web. Permanent tunnels were found under any large log that has been laying on the ground. Moreover, tunnels were found anytime a shovel was pushed into the soil. This is not the case in the meadow where the soil is wetter, sandier, and more compact. Mole hills were rarely seen in the flatwoods probably because the soil was a loose, deep organic layer easily tunneled through.

On 6 January 2023 at 8:13 pm, a trail camera photographed a Barred Owl on the ground in the flatwoods holding a mole in its bill. Barred Owls hunt many species of moles in North America, which are their second most common prey behind rodents (Livezey 2007). Five voucher specimens were collected from the flatwoods and meadow (JJK-4929, JJK-4942, JJK-4944, JJK-5013, JJK-5014).

ORDER CHIROPTERA
Family Vespertilionidae
***Eptesicus fuscus* (Palisot de Beauvois, 1796)**
Big Brown Bat

Eptesicus fuscus is a year-round resident found throughout Kentucky. It was once one of the most common bats in the state but is in decline due to white-nose syndrome (WNS; Cheng et al. 2021). *Eptesicus fuscus* was observed flying over the meadow shortly after sunset on multiple occasions. Typically, only one was observed on a single evening. There were 36 detection files of the species from the meadow and five from the flatwoods (Table 7). Maximum likelihood for them was recorded three times for the meadow and once for the flatwoods (Table 8). There is no evidence *E. fuscus* uses the two outbuildings for roosts.

***Lasionycteris noctivagans* (LeConte, 1831)**
Silver-haired Bat

Lasionycteris noctivagans is thought to have a short migratory stopover in Kentucky before it continues to northeastern North America where it spends its summers (Barbour and Davis 1969; McGuire et al. 2012). It was detected in the meadow 34 times and in the flatwoods 12 times (Table 7). A significant maximum likelihood of its occurrence was determined three nights in the meadow and once in the flatwoods (Table 8). *Lasionycteris noctivagans* roosts in hollow trees, tree cavities, and crevices beneath peeling bark (Barbour and Davis 1969). Such habitat is not abundant in the preserve; thus it is unlikely more than a few of these bats could remain during the summer. Thus, it is not known whether the *L. noctivagans* detected during June 2025 were summer residents or migrants. Kentucky is close enough to the summer range that some bats could remain as summer residents.

***Lasiurus cinereus* (Palisot de Beauvois, 1796)**
Hoary Bat

Lasiurus cinereus is a foliage roosting species (Barbour and Davis 1969) and a longitudinal migrant (Cryan et al. 2014) with females found statewide during summer months. There were 18 detection files

of *L. cinereus* from the meadow and only one from the flatwoods (Table 7). The maximum likelihood of occurrence was significant in the meadow for two nights and no nights in the flatwoods (Table 8). In the preserve, they probably roosted in trees near the edge of the meadow. On 20 July 2023, a freshly dead female was found on the trail that circles the meadow. The neck and head showed extensive trauma and blood as if bitten by another bat, as the puncture wounds were the size that could have been made by bat teeth. *Lasiurus cinereus* is known to be aggressive to other bats (Bishop 1947; Ore 1950; Wine et al. 2019), thus it is possible another *L. cinereus* killed it. This bat is voucher specimen JJK-4822.

***Lasiurus borealis* Müller, 1776**
Eastern Red Bat

Lasiurus borealis is the smallest of the foliage roosting bats. It hangs among leaves by one foot giving the appearance of being a dead leaf (Barbour and Davis 1969). *Lasiurus borealis* is a statewide and year-round resident in Kentucky. It is also considered a migratory species (Barbour and Davis 1969). This suggests that northern summer residents may migrate south to Kentucky for the winter, whereas those that are summer residents in Kentucky may migrate farther south for the winter. *Lasiurus borealis* are often observed flying over the meadow at sunset. This is the most frequently observed bat in the preserve. Results from the bat detector also indicate it is the most common bat. The bat detector recorded 116 files identified as *L. borealis* in the meadow and 1,023 files of them in the flatwoods (Table 7). The maximum likelihood estimates were highly significant for both flatwoods and meadow (Table 8).

***Nycticeius humeralis* (Rafinesque, 1818)**
Evening Bat

Barbour and Davis (1969, 1974) describe *Nycticeius humeralis* as a southern species considered rare in Kentucky. It occurs mostly in the western third of the state. *Nycticeius humeralis* emerges early in the evening and has a slow, steady flight. This, along with being smaller than *E. fuscus*, makes it readily identifiable. Barbour and Davis (1969) described their flight as distinct such that an "experienced observer" can recognize them by their flight. An evening bat was observed flying low over the meadow shortly after sunset on 19 July 2024. There were 17 detection files for it in the meadow and 118 for the flatwoods (Table 7); however, the maximum likelihood of these records being *N. humeralis* was only statistically significant for the flatwoods on 1 June 2025 (Table 8). This bat has summer roosts behind the bark of dead trees, in hollow trees, and tree cavities. Maternity roosts are known to occur in buildings (Barbour and Davis 1969), but there is no evidence this bat has roosted in either outbuilding at the Preserve. Large, hollow trees with dead bark are not abundant in the preserve. Thus, potential summer roosts are rare.

***Perimyotis subflavus* (Cuvier, 1832)**
Tricolored Bat

Perimyotis subflavus is a forest-edge species that avoids deep woods and open fields unless there are large trees nearby (Barbour and Davis 1969; Hein et al. 2009). This is one of the two smallest species of bats in Kentucky. *Perimyotis subflavus* is highly susceptible to WNS, which has resulted in a sharp population decline in Kentucky and over most of its range. This bat is typically the first to fly over the meadow yet close to the trees at sunset. The flight is characteristically rapid and erratic. At most, four individuals were seen flying at one time. There were four files identified as Tricolored Bats from the meadow and 78 from the flatwoods (Table 7). The maximum likelihood of occurrence was significant for two nights in the flatwoods (Table 8). Thus, these bats were more associated with the flatwoods either flying above or under the canopy where the understory was fairly open.

ORDER CARNIVORA
Family Mephitidae
***Mephitis mephitis* (von Schreber, 1776)**
Striped Skunk

Mephitis mephitis is statewide and common in Kentucky. It inhabits a wide variety of habitats including mixed woodlands, open fields, woodland edges, brushy fields and open fields interspersed with wooded ravines, and areas with cliffs and complex rock formations (Barbour and Davis 1974). *Mephitis mephitis* was common in Hazeldell Preserve. Eleven individual skunks were photographed from September 2022 to April 2023. Identification was based on differences

in color patterns. They were drawn to a wide variety of scent stations with a preference for mustelid scent gland stations visiting these 54% of the time (Kruger et al. 2024), and they were photographed at scent gland stations 10 times more often than at bait stations with lard, sardines, and peanut butter (Tierney et al. 2022; Kruger et al. 2024).

Family Mustelidae
***Neogale frenata* (Lichtenstein, 1831)**
Long-tailed Weasel

Neogale frenata has a statewide distribution in Kentucky. Barbour and Davis (1974) considered it fairly common, yet it is secretive and rarely seen. *Neogale frenata* is found in a variety of habitats including brushy areas, open woodlands, grasslands, fencerows, weedy areas along roads, and areas with tall grass along wet and marshy areas. Barbour and Davis (1974) described the habitat as forest edge, brushland, fencerows, and streambanks. This species was photographed in the preserve four times from 6 September to 1 October 2022. It appears these photos were of the same individual, apparently a female based on small size. All photos were taken in the wettest area of the preserve near a pasture (Fig. 7). Considering the only photos were from a three-week period, this was likely a transient weasel. *Neogale frenata* is a habitat generalist occurring in fragmented areas (Crooks 2002; Gehring et al. 2021). Hazeldell Preserve is part of a mosaic of agricultural fields and woodlands. The surrounding farms and forest edges are more suitable habitat than is the preserve. Rodents were not abundant in the flatwoods and the meadow was likely too small to sustain a large enough population of *P. leucopus* and *M. ochrogaster* to sustain a weasel. Further, *N. frenata* requires pre-existing, below-ground burrows (Sheffield and Thomas 1997) such as those made by Eastern Chipmunks (*Tamius striatus*) and Woodchucks (*Marmota monax*), neither of which occurred in the preserve apparently due to the secondary water table (Tierney et al. 2022).

***Neogale vison* (von Schreber, 1777)**
American Mink

Neogale vison is statewide and semi-aquatic, usually associated with permanent water such as streams, rivers, marshes and lakes (Larivière 1999). It is a capable swimmer, and particularly with males, it can travel great distances on land. Schwartz and Schwartz (2016) describe *N. vison* as intermediate between an otter and a weasel. There were only three photographs of *N. vison* in the preserve. These were taken on 15 November 2022, 18 December 2022, and 9 February 2023. Hazeldell Preserve lacks permeant water and sufficient prey necessary for *N. vison*, thus the photographs are likely of one or more transients.

Family Procyonidae
***Procyon lotor* (Linnaeus, 1758)**
Northern Raccoon

Procyon lotor is abundant and found statewide. Its preferred habitat includes forests, brushland, farmland, and urban areas. As an opportunist and omnivore, *P. lotor* can be a destructive predator of reptile eggs and bird nests, eating both eggs and young. Its diet shifts with changing seasons focusing on whatever food is available including seeds of the following: junipers, persimmons, wild grapes, greenbriers, and blackberries. In early fall, it is not uncommon to find their droppings packed solid with persimmon seeds.

Procyon lotor occurred in both the flatwoods and the meadow. Footprints were commonly seen on wet soil. It was a major predator of crayfish especially in the meadow where these crayfish were most abundant. Quite often, *P. lotor* dug crayfish out of their burrows, often leaving their pincers behind along with large holes from the excavation. *Procyon lotor* is one of the major causes of soil disturbance in the meadow. Evidence of digging for crayfish in the flatwoods was rare, despite an abundance of crayfish. *Procyon lotor* were only photographed on six occasions in the spring of 2020 (Tierney et al. 2022), whereas there were 305 images of them in 2022 and 2023 when predator scents were used (Kruger et al. 2024). This was a 41-fold increase. Of the 305 photographs, 42 had two individuals, and two had three individuals. After the March 2025 prescribed burn of the meadow, trail cameras photographed *P. lotor* foraging, and at that time the below ground nest chambers of *M. ochrogaster* were being dug up, suggesting this was by *P. lotor*.

Family Ursidae
***Ursus americanus* Pallas, 1780**
American Black Bear

Before European settlers arrived, *Ursus americanus* was common in Kentucky. During the 1800s and early 1900s, populations declined sharply due to habitat loss and unregulated hunting. By 1925, the species was thought to be nearly exterminated in the state (Funkhouser 1925). By 1974, it was considered extirpated (Barbour and Davis 1974). Since then, protection and reintroductions in Tennessee have led to recovery. Currently there are an estimated 1,000 to 1,500 *U. americanus* in Kentucky. A sighting in the preserve was reported in 2015. The person's dogs were barking hysterically at a large black animal in the flatwoods at dusk. A male *U. americanus* was reported near the preserve around that time (Unger et al. 2013). As the population continues to increase, *U. americanus* may become established in the preserve and the surrounding areas.

Family Canidae
***Canis familiaris* Linnaeus, 1758**
Domestic Dog

Canis familiaris was never seen in the preserve from May 2012 to September 2022. It was not photographed during the first camera study (Tierney et al. 2022) when peanut butter, sardines, and lard were used for bait. In contrast, eight different *C. familiaris* were photographed during the second camera study when commercial predator scents baits were used (Kruger et al. 2024). In fact, they were the third most photographed carnivore (Table 2). On three occasions during that study, they were observed running away when cameras were being checked. No *C. familiaris* have been seen in the preserve since the study ended in March 2023. This suggests the scent baits attracted *C. familiaris* from nearby farms.

***Canis latrans* Say, 1823**
Coyote

Canis latrans was first confirmed in Kentucky in 1953 (Gale and Pierce 1954) and has since expanded across the state. *Canis latrans* was the second most photographed carnivore in the flatwoods when scent baits were used, appearing in 79 photographs (15% of all images; Kruger et al. 2024), which was a 10-fold increase from the eight (1.4%) images taken by Tierney et al. (2022) when scent baits were not used. Open pastures and crop fields surrounding the preserve are their preferred habitat (Kamler and Gipson 2000; Larrucea et al. 2007). Thus, *C. latrans* was more typically in the surrounding agriculture near the preserve. They were probably drawn into the flatwoods because of the predator scent baits there from 3 September 2022 to 26 March 2023.

***Urocyon cinereoargenteus* (von Schreber, 1775)**
Northern Gray Fox

Urocyon cinereoargenteus was only photographed three times in the winter of 2020 (Tierney et al. 2022) and not at all in 2022 and 2023 (Kruger et al. 2024). The absence of this fox in the preserve was most likely a lack of suitable habitat. *Urocyon cinereoargenteus* prefers mature hardwood forests of eastern North America (Rich et al. 2018), however, they can occur in agricultural areas, especially when other species of canids are absent (Rich et al. 2018). Because Hazeldell Preserve lacks mature hardwood forest, *U. cinereoargenteus* is only an occasional visitor.

***Vulpes vulpes* (Linnaeus, 1758)**
Red Fox

Vulpes vulpes is the most widely distributed species of carnivore in the world, found throughout the northern hemisphere and areas of North Africa. Prior to European settlement, *Vulpes vulpes* was a northern, boreal species absent from the southern part of North America, including Kentucky. It is now common in Kentucky and found statewide. *Vulpes vulpes* is an edge species preferring habitat diversity with crop fields, pastures, edges of woods, and brushy areas (Barbour and Davis 1974). Abundance of prey appears more important than habitat for this species (Larivière and Pasitschniak-Arts 1996). In the preserve, the flatwoods had little prey for *V. vulpes*. Small mammals were more abundant in the meadow, but the vegetation was tall and dense, thus likely difficult for predators to hunt. *Vulpes vulpes* was not recorded during the first camera study in 2020 (Tierney et al. 2022). It was photographed on 12 separate occasions from November 2022 to March 2023 when predator scents were used (Kruger et al. 2024). Nine of the 12 photographs were of *V. vulpes* visiting scent bait stations with mustelid scents (fisher, mink, weasel; Kruger et al. 2024). Thus, it appears,

as with other carnivores, scent baits were drawing *V. vulpes* into the preserve from surrounding agricultural areas. After the 10 March 2025 prescribed burn, trail cameras photographed *V. vulpes* in the meadow twice in the following weeks.

Family Felidae
***Felis catus* Linnaeus, 1758**
Domestic Cat

There was only one record of *F. catus* in the preserve. It was photographed at a mink scent station on 3 November 2023 at 9:23 pm.

***Lynx rufus* (von Schreber, 1777)**
Bobcat

Barbour and Davis (1974) considered *Lynx rufus* rare in Kentucky, due to its decline in eastern states after European settlers arrived (Patton 2011). Since the mid-1990s, *L. rufus* numbers in North America and Kentucky have increased appreciably. Today, there may be more than 4 million *L. rufus* in North America (Roberts and Crimmins 2010). *Lynx rufus* is one of the few successful carnivore recoveries. It prefers extensive mature forests (Lesmeister et al. 2015), and yet it is one of the most common carnivores roaming the preserve. It was photographed six times in the spring of 2020 (Tierney et al. 2022), which was more than other carnivores except *C. latrans*. When using predator scents, trail cameras recorded 24 photographs of three different individuals (Kruger et al. 2024). Sixty-seven percent of the photographs were of *L. rufus* investigating scent baits, 46% of these were mustelid scent gland lures. The other 33% of the photographs were of *L. rufus* walking through the flatwoods.

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Family Cervidae
***Odocoileus virginianus* (Zimmermann, 1780)**
White-tailed Deer

Odocoileus virginianus is considered an edge species in Kentucky, preferring woods that border open areas. Furthermore, *O. virginianus* is synanthropic, meaning a species well-suited for life near humans. Farmlands, suburbs surrounded by forests, patches of forest where logging has occurred, and along roadsides are preferred habitat. Due to unregulated hunting and market hunting, the population in Kentucky declined to fewer than 2,000 deer statewide by 1900. By the 1950s, the *O. virginianus* population began to increase due to strict hunting regulations and restocking programs. Currently, the Kentucky Division of Wildlife Resources estimates there are 1,000,000 *O. virginianus* in the state. The fragmented landscape surrounding the preserve with its mosaic of wooded areas, pastures, and crop fields is prime habitat. Consequently, the *O. virginianus* population is large in the preserve. Furthermore, the preserve is closed to hunting, thus serving as a refuge. Almost 100% of plants favored by this species, including three species of Greenbriers (*Smilax* sp.) and Strawberry Bush (*Euonymus americanus*) were browsed frequently. *Odocoileus virginianus* was photographed in the preserve 87 times in the spring of 2020, which was 15.7% of all photographs taken with trail cameras (Tierney et al. 2022). Kruger et al. (2024) did not record the number of photos taken of *O. virginianus*; however, many showed deer walking behind the scent stations, including nine different bucks.

DISCUSSION

Thirty-three species of mammals were confirmed in Hazeldell Meadow State Nature Preserve during this study. Two species were non-natives; *C. familiaris* and *F. catus*. Five native species were considered transients: *Z. hudsonius*, *S. niger*, *N. frenata*, *N. vison*, and *U. americanus*. Four native species that are likely breeding residents were rarely caught during the study: *C. parvus*, *M. pinetorum*, *S. longirostris*, and *S. cooperi*. One *Mus musculus* was trapped 8 m from the west boundary of the preserve on the last day of the study.

Fassler (1974) documented 11 species of bats for Pulaski County, many of which are associated with caves in the southeastern part of the county. Only six were confirmed in Hazeldell Preserve. The Northern Long-eared Bat (*Myotis septentrionalis*) was probably in the flatwoods before its sharp population decline from WNS. Similarly, *M. lucifugus* may have been present before WNS as well. There is no evidence that this species ever used the cinder block outbuilding on the preserve as a maternity roost. Of the species

of bats Fassler (1974) documented in the county, *M. lucifugus*, *M. sodalis*, and Eastern Small-footed Myotis (*Myotis leibii*) may occasionally forage over the preserve. Gray Bats (*Myotis grisescens*) are abundant in nearby caves, but they forage over permanent water including streams, lakes and reservoirs (LaVal et al. 1977), all of which were lacking in or near the preserve. Rafinesque's Big-eared Bats (*Corynorhinus rafinesquii*) are also in caves close to Hazeldell Preserve, but they feed on moths in mature forests not far from their roost caves, thus it is unlikely they forage over the preserve. The lack of sufficient large dead and hollow trees does not provide enough summer roosts for *M. sodalis*, *M. septentrionalis*, and *N. humeralis*. These species could be attracted to summer roosts in the preserve if rocket boxes or BrandenBark (Copperhead Consulting, Inc., Paint Lick, KY) roosts were erected in the meadow. Modifications to the cinder block outbuilding could make it a more suitable summer roost for *M. lucifugus*.

Trail cameras have become an important field tool for documenting species (Schlexer 2008; Buyaskas et al. 2020). This was especially true for carnivores that are by nature less common than other species. In this study, 10 of the 11 species of carnivores were documented by using cameras. Cameras in this study were most effective when used with commercial scent baits, especially those with glandular secretions (Kruger et al. 2024), as Randler et al. (2020) and Fidino et al. (2020) also demonstrated. For example, when using sardines, peanut butter, and lard as bait, only 28 of 34,071 photographs taken were of five species of carnivores (Tierney et al. 2022). When using glandular scent baits as attractants, 523 of 34,071 photographs taken were of 10 species of carnivores (Kruger et al. 2024).

Of the two species of tree squirrels, *S. carolinensis* was the most abundant in the preserve, whereas *G. volans* was uncommon. They both use cavities for nests and refuges, and they both have similar diets that include nuts and acorns, although *G. volans* is more carnivorous (Dolan and Carter 1977). Also, the size of cavities used by each species differs with *G. volans* preferring smaller cavities such as those made by woodpeckers, whereas *S. carolinensis* uses larger cavities found in hollow and dead trees. Both species prefer mature hardwood forests, which was lacking in the preserve. There is no published research suggesting these two species compete, thus it is unclear why one species was extremely common and the other rare.

There has been no evidence of *M. monax* and *T. striatus* in the preserve after 14 years of observations. The flatwoods, at first glance, would appear ideal for both species, especially *M. monax* along the edge of the boundary. A juvenile roadkill *M. monax* was found 410 m west of the preserve on 20 July 2023. This location was along Ocala Road where the soil is well drained due to lack of a fragipan. The best explanation for the absence of these two species is that the secondary water table created by the fragipan prevents constructing deep burrows. Additionally, standing water persists over portions of the preserve from late fall to early spring, which would flood the burrows used for hibernation.

Urocyon cinereoargenteus prefers mature forests in eastern North America, however, it can occur in agricultural areas, especially when other species of canids are absent (Rich et al. 2018). Furthermore, the presence of *C. familiaris, C. latrans*, and *V. vulpes* could deter *U. cinereoargenteus* from frequenting the preserve. Thus, it was not surprising *U. cinereoargenteus* was rarely photographed. Possibly, in the future, as trees in the flatwoods mature, the preserve will provide more suitable habitat.

Since 1987, the Mexican Long-nosed Armadillo (*Dasypus mexicanus*) has expanded its range over most of Kentucky. It has been sighted in Pulaski County near the preserve and immediately north in Garrard and Lincoln counties. It is almost certain *D. mexicanus* will become established in eastern Kentucky in the near future (Moncrief et al. 2021) possibly including Hazeldell Preserve. *Dasypus mexicanus* erratically digs in soil when foraging (McBee and Baker 1982), thus it has the potential to cause new forms of disturbance impacting the ecology of the preserve. However, this species is a burrower (McBee and Baker 1982). Thus, as with *M. monax* and *T. striatus*, the wet soil conditions may prevent *D. mexicanus* from becoming common in the preserve.

In reality, small mammals were not abundant or diverse in the preserve compared to other locations in Kentucky. Before 2022, *P. leucopus* and *S. carolinensis* were the only two common small mammals. *Microtus*

ochrogaster became abundant after it was first documented in 2022. It is not certain why small mammal abundance is low. It is possible the secondary water table resting atop the fragipan has altered the habitat so that it is not favorable to small mammals. With this point aside, the rarity of some species remains a mystery.

This study has shown that the mammal ecology of Hazeldell Meadow State Nature Preserve is dynamic, especially in the wet meadow. It is likely there will continue to be changes in the abundance, diversity, and richness of mammal species in the preserve along with the potential for new species to arrive. The future ecology of the preserve is vulnerable to surrounding forest fragmentation, changes in surrounding agricultural practices, and logging. Climate change caused by global warming could result in the preserve becoming drier. The impact this will have on mammal ecology will only be known with future research.

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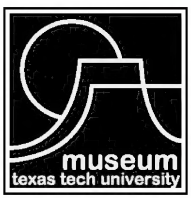

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